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ABSTRACT

A battery of memory tests was administered to 243 male university students. Factor analysis with oblique rotation of factors revealed five factors: (1) associative memory (particularly important in paired-associate tests), (2) short-term visual memory (the ability to derive information from briefly presented visual displays), (3) meaningful memory (based on vocabulary and memory for text material), (4) visual memory (defined by memory tests involving geometric figures), and (5) span memory (the ability to remember a short series of items in their presented order). Second order factoring produced two factors--strategic memory (defined by associative, meaningful, and visual memory); and nonstrategic memory (defined by short-term visual and span memory). Tests loading on the strategic memory factor afforded the use of various processing strategies while tests loading on the nonstrategic factor did not provide much opportunity for the use of strategic processing. Cluster analysis of subjects produced five categories, three of which had fairly uniform score profiles across the five first order memory factors. The remaining two groups had profiles that exhibited good short-term visual and span memory abilities, relative to other memory abilities. General results support the second order factor analysis and the distinction between strategic and nonstrategic memory abilities and tasks. (Author)

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Factor Analysis and Cognition: A Study of Memory Processes

(Paper presented at the meetings of the American Psychological Association,
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The area of cognitive psychology has primarily been associated with univariate methodology. Recently, however, there has been increasing interest in individual differences in the realm of cognitive abilities. There is a growing realization among some cognitive psychologists that multivariate techniques can be effectively used in the study of cognition. It is conceivable that multivariate research on issues in cognitive psychology can lead to theoretical insights as well as practical implications that would not otherwise be apparent.

On the other hand, some multivariate research on cognitive abilities exists in the literature, but often this research has been concerned with problems not directly relevant to contemporary issues in cognitive psychology. This has been particularly true of multivariate research on memory. This research originated with studies of primary mental abilities. In that context, memory tests usually formed a single factor. Later, more specialized studies suggested the existence of other factors, and the issue of the number and nature of memory factors began to develop. Evidence for the existence of separate associative and meaningful memory factors indicated that subjects deal with associative memory tasks, such as paired associate learning, in ways that differ significantly from the processes they use to encode meaningfully related material, such as stories.

Another memory ability that became prominent in factor analytic studies was span memory. This factor generally involved tests requiring subjects to immediately recall a series of unrelated items in the correct order. A visual memory factor has also been identified, although its basis is rather tentative.

While identification of these various memory factors has been an important part of our understanding of memory processes, critical issues have been inadequately represented in this research. One such issue deals with the relationships between the various memory abilities. In his 1964 monograph, Kelley presented one of the most ambitious multivariate studies of memory to date. In his analysis, however, Kelley used only orthogonal rotation of factors, precluding a systematic investigation of the relationship between factors that would have been available through such techniques as higher order factoring. The second major shortcoming apparent in the multivariate literature on memory has been the relative lack of discussion of implications for issues in cognitive psychology. There have been some examples, however, of attempts to extend results of multivariate research to topics of concern in the univariate literature. Early examples include work on serial learning and its relationship to span and associative memory. More recently, various types of span tests have been related to short-term and iconic memory.

The present experiment, therefore, was designed with two objectives in mind. The first was to investigate a variety of memory factors in a single experiment so that the relationships among these factors could be studied. The second was to design the memory tests so as to be relevant to contemporary issues in univariate research on memory processes. The resulting set of memory tests included paired associate learning tasks, tests of paragraph memory, visual processing and memory tasks, short-term or

or span memory tests, and tests similar to iconic memory tasks. These tests were designed to represent associative, meaningful, visual, span, and short-term visual memory, respectively. The last proposed memory factor is similar to iconic memory, except that exposure durations of stimuli were longer than those typically used in iconic memory experiments. The term for the processes involved in tasks using these longer stimulus durations is short-term visual memory. The test battery, then, was constructed so that a broad range of memory processes could be sampled.

Method

Description of the Test Battery

A summary of the test battery is provided in Table 1. The group of tests designed to form an associative memory factor was composed primarily of paired associate tasks. Subjects would study pairs of items and were responsible for recalling the second member of each pair, given the first member as a cue. The items used in these tests included numbers, consonant-vowel-consonant trigrams, and words. One of the tests followed a free recall format in which a list of unrelated words was studied and subjects were then required to recall as many of the items as possible.

The set of tests dealing with short-term visual memory all involved a 500-millisecond presentation of a matrix of digits, letters, or words. Subjects were required to fill out a blank matrix by writing the items they remembered in the correct positions.

Meaningful memory was tested with paragraph memory tests and a standardized vocabulary test. Visual memory tests involved geometric figures that bore no direct relationship to any real object. These tests used paired associate, free recall, recognition, and span memory formats as well as a test of manipulation of visualized objects.

The span memory tests required subjects to remember information about the order of items presented, the items themselves, or both. Items included letters, digits, and words.

Subjects

The tests were administered to 243 male students at the University of Colorado.

Procedure

The tests were administered over two sessions and the order of presentation was arranged so that subjects were not faced with the same type of material or test format in consecutive tests.

Results

Performance on the tests was scored for each subject, and the correlation between each pair of tests was calculated. The resulting correlation matrix was factor analyzed. The results of a maximum likelihood factor analysis indicated that a five-factor solution was optimal. All but 12 of 231 residual correlations were in the range $\pm .10$. Oblique rotation of factors was carried out using a generalized form of the Harris-Kaiser "Case II" method.

The obtained primary factor pattern matrix closely followed the expected pattern of results. The factor loadings are shown in Table 2. Only loadings of at least .2 are shown and decimal points have been omitted. Some tests have loadings of .2 or higher on more than one factor. Factor I was defined primarily by the paired associate tests involving verbal material and the free recall test had its highest loading here. This factor was interpreted as associative memory. The tests of short-term visual memory and the span memory test involving recall of items without regard to input order defined Factor II. This factor was interpreted as short-term visual memory. Factor III was interpreted as meaningful memory since substantial loadings were contributed by the paragraph memory and vocabulary tests. All tests dealing with geometric figures loaded highly on Factor IV, defining it as visual memory. Finally, the span tests dealing with memory for order of presentation or with memory for both items and their order of presentation loaded highly on Factor V. This factor was interpreted as span memory.

A second order maximum likelihood factor analysis of the five original factors revealed two general factors (Table 3). The first was defined primarily by the span and short-term visual memory factors. The other second order factor was defined by the remaining three factors: associative, meaningful, and visual memory.

Next, individual subject scores on each of the five first order factors were analyzed using Ward's hierarchical grouping method. Five groupings of subjects were selected on the basis of their scores on the first order factors. Score profiles for each of the groups are shown in Figure 1. Group 1 scored well on all factors, Group 4 was average, and Group 5 was consistently low on all factors. Groups 2 and 3 had their highest scores on short-term visual and span memory, and lower scores on the other factors. Group 2 scored at or above the mean on all factors while Group 3 achieved average or better scores only on short-term visual and span memory. A discriminant function analysis of these five groups based on first order factor scores produced two significant functions (Figure 2). The first function provided discrimination based on all factors, representing a general memory function. The second function discriminated on the basis of groups that scored higher on short-term visual and span memory than on other factors. These results provide converging evidence for the functional significance of the two second order factors obtained in the higher order factor analysis.

Discussion

Clear evidence for a visual memory factor supports suspicions about the existence of such a factor that have been in the multivariate literature for some time. It also implies that cognitive theories about visual information processing should seriously consider the existence of special processes for dealing with visual material. Span memory was shown to be closely related to memory for order information, as the span test involving recall of items without regard for input order failed to load on the span memory factor. This result provides further insight into the nature of span memory as well as converging evidence for the distinction currently being made in cognitive psychology between item and order information. Evidence for the existence of a new memory factor, short-term visual memory, was also provided.

The second order factor analysis indicated that at least two general memory factors exist. One can be classified as a nonstrategic processing factor, involving tests in which subjects are not able to make use of well developed or higher order cognitive strategies. The other can be viewed as a strategic processing factor that involves the ability to develop and use complex processing strategies. This distinction was also apparent in the analysis of subject clusters. Certain types of subjects were no better

at dealing with nonstrategic tests than with strategic ones, while others were particularly good at tests not requiring the use of relatively complex strategies.

These results suggest a promising approach to the study of individual differences in memory. Once a set of memory factors has been established, one can proceed to identify members of a population who are particularly adept at various kinds of memory tasks. These strengths and weaknesses can be used to further study memory processes and, from a practical standpoint, they can assist in evaluating aptitude for specific types of employment. The degree of success in applying multivariate techniques to the study of cognition is promising and extensions of this methodology are strongly encouraged.

Table 1

Summary of First Order Memory Factors and Memory Tests

<u>Factor</u>	<u>Test</u>
I Associative Memory	Word-number paired associates Word-CVC trigram paired associates Abstract noun paired associates Concrete noun paired associates Abstract noun-adjective paired associates Concrete noun-adjective paired associates Free recall of words
II Short-Term Visual Memory	Short-term visual memory for letters Short-term visual memory for digits Short-term visual memory for words Unordered letter span
III Meaningful Memory	Vocabulary Memory for concrete text Memory for abstract text
IV Visual Memory	Span memory for geometric figures Geometric figures paired associates Recall of geometric figures Recognition of geometric figures Visual rotation
V Span Memory	Digit span Digit span recognition Span memory for words

Table 2
First Order Factor Loadings

Variable	I	II	Factor III	IV	V	Commun- ality
Paired Associate Tests	57 33 63 65 79 49 25					31 32 54 51 68 35 34
Free Recall						
Short-Term Visual Memory Tests		56 73 42 35	26			33 56 28 29
Unordered Span						
Vocabulary Paragraph Memory Tests			69 39 41			48 29 30
Visual Memory Tests		20	23	37 39 57 40 41		30 21 40 25 18
Visual Rotation						
Ordered Span Memory Tests				25	64 35 55	40 31 44

Table 3
Second Order Factor Loadings

First Order Memory Factor	Second Order Factor		Commun- ality
	A	B	
Associative	23	70	64
Short-Term Visual	36	08	16
Meaningful	27	44	34
Visual	15	51	33
Span	99	00	99

Figure 1. Factor scores of each of the five groups on the first order factors.

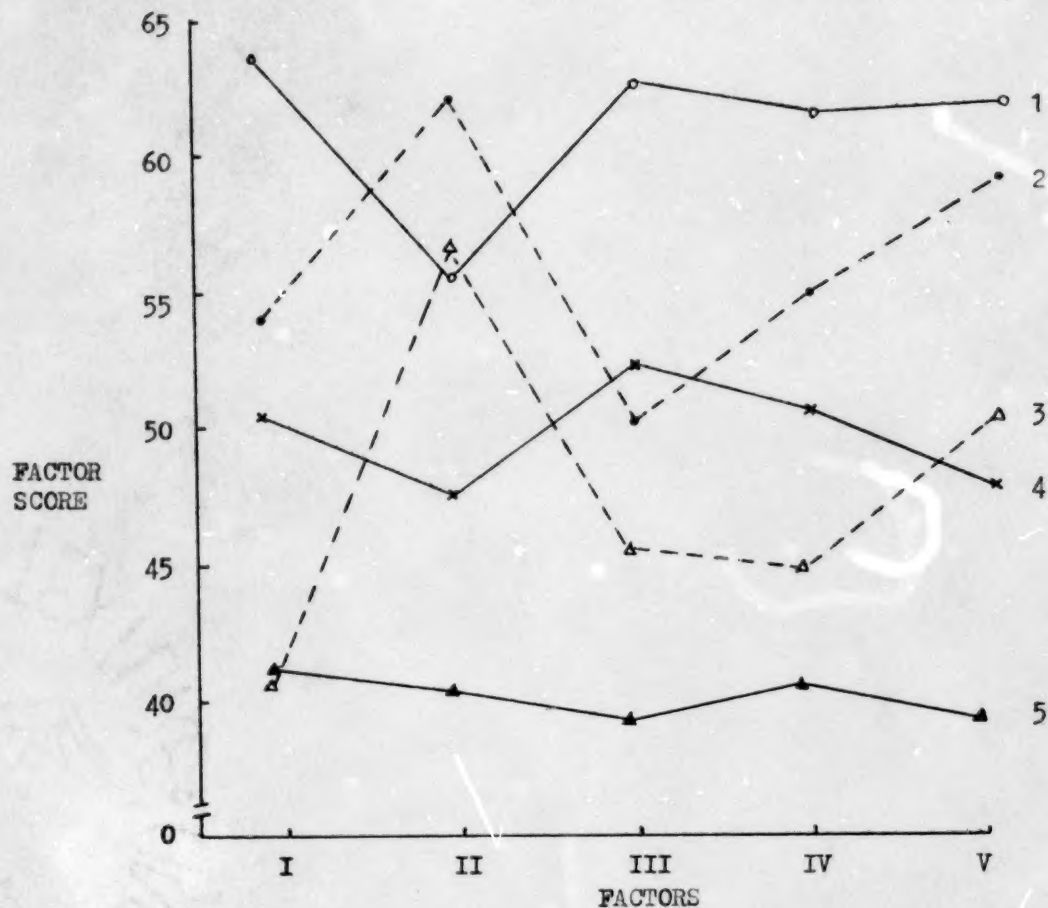


Figure 2. Discriminant function scores of the five groups.

